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CONCEPTION OF NEW TECHNIQUES AND EQUIPMENT FOR THE PRODUCTION OF NON-ELECTRIC DETONATORS

Nathan D. Isaacs

MRC Corporation

Prepared for:

Picatinny Arsenal

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FINAL REPORT

by

NATHAN D. ISAACS

MAY 7, 1975

PICATINNY ARSENAL

DOVER, NEW JERSEY 07801

CONTRACT NO. DAAA21-73-C-0101

MRC CORPORATION

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ABSTRACT

A program was conducted to conceive new techniques and equipment for the production of non-electric detonators at the rate of 1200 per minute. MRC conducted an engineering study of the operations required for loading the M55 non-electric detonator and performed material response testing on the three explosives (RDX, lead azide, NOL 130), used in that item. A bench model rotary loading press, identical in design to a production machine, was designed and fabricated, and live loading runs were performed, to demonstrate the feasibility of MRC's concepts. Successful test runs were made with all three explosives. The ability to produce a uniform product in accordance with the M55 drawing requirements at the desired production rate was demonstrated. It has been concluded that it is feasible to load 1200 M55 detonators per minute using MRC's rotary loading concepts.

FOREWORD

This program was performed by the MRC Corporation, Baltimore, Maryland, for the Manufacturing Technology Directorate, Picatinny Arsenal, Dover, New Jersey, under U.S. Army Contract No. DAAA21-73-C-0101. The Picatinny Arsenal Project Officer was Harold Kesselman. The principal investigator was Nathan Isaacs. This is the final report for the work completed under this contract.

TABLE OF CONTENTS

Section	Page
Abstract	iii
Forward	v
SUMMARY AND CONCLUSIONS	1
SUMMARY OF TESTS PERFORMED	5
BENCH MODEL DESCRIPTION	7
HAZARDS ANALYSIS	17
LIVE LOADING RUNS	25
APPENDIX A. PRELIMINARY SIMULANT TESTS	31
APPENDIX B. INERT BENCH MODEL TESTS	37
APPENDIX C. LIVE BENCH MODEL TESTS	57
APPENDIX D. PRESS SIMULATOR	69

SUMMARY AND CONCLUSIONS

The following paragraphs briefly review MRC's original concept, objectives and accomplishments for this program, present recommendations for future work effort and present a condensation of MRC's testing with live explosives.

CONCEPT

MRC's Gravity-Feed Rotary Press loading concept utilizes three standard rotary compaction presses operating in sequence. Explosives are fed by gravity into an adjustable cavity in the rotary dial and compacted into detonator cups. MRC's projected prototype system follows the design principles of the Tracer Charging Submodule being built by MRC for the SCAMP program. The rotary compaction presses utilized in MRC's system presently are used for pelletizing RDX at Lonestar, AAP.

OBJECTIVES

- Perform an engineering study of the operation of loading non-electric detonators.
- Conceive new techniques and equipment to perform these operations at the rate of 1200 per minute.
- Fabricate a bench model sufficient in details to establish the basic feasibility of MRC's Gravity-Feed, Rotary Press concepts.
- Perform inert and live tests using the bench model to demonstrate feasibility.

ACCOMPLISHMENTS

- MRC has constructed a bench model identical in design to a production machine, the only significant functional variation being the number of operating stations.
- MRC has successfully loaded all three explosives (as well as approved simulants) into M-55 detonator cups.
- MRC has demonstrated the ability to produce a uniform product in accordance with the drawing requirements for the M-55 detonator at the desired production rate.

HARDWARE

MRC's bench model is a single station rotary compaction press operating at 25 RPM. Explosives are gravity fed from a feed frame and the detonator cups are handled in nests. A 1200 per minute production machine would be identical in design except that 48 stations would be utilized. However, it is important to note that the bench model exactly duplicates the operating conditions on a production machine.

TESTING

During the course of this program MRC has compl^ted the following test programs:

- A series of sensitivity tests on the three explosives and a preliminary hazards analysis of MRC's concept (performed by Allegany Ballistics Laboratory). ABL concluded that adequate safety margins exist for all normal operations.

- A series of dynamic fill tests with inert materials to generate feed frame design criteria. MRC also performed basic physical property tests on the inert simulants.

- A series of live tests on a simulator which duplicates the diameter and speed of MRC's bench press.

- An extensive series of tests with all three explosives on MRC's bench press. These tests included long duration runs with lead azide and NOL 130 without nest feed as well as standard loading runs.

MOST SUCCESSFUL CONFIGURATIONS

Our test results indicate that only one press configuration is required to successfully load all three explosives. Aside from punch settings the only differences between presses are feed frame construction. The respective feed frame designs that were most successful are as follows:

- RDX - A five compartment fixed feed frame with an Oilon bearing surface was used effectively. It is felt that a smaller two or three compartment feed frame would be adequate.

- Lead Azide - A one compartment floating feed frame with a hardcoated aluminum bearing surface was used without incident. Two independent feed frames of this design are indicated for a prototype machine.

- NOL 130 - A five compartment floating feed frame with an Oilon bearing surface is the preferred configuration. A pneumatic vibrator was used to prevent bridging of the NOL 130. Undercuts on the bearing surface lands between compartments were used to promote movement of the explosive within the feed frame since proper metering is dependent upon controlled circulation of the NOL 130.

BENEFITS OF MRC'S SYSTEM

- MRC's bench model exactly duplicates the operating conditions of a production machine.
- Commercially available Colton 247 rotary loading presses can be used to handle all three explosives.
- Press construction is virtually identical for all three explosives.
- No moving mechanisms are required for metering explosives. Thus reliability and maintainability should be quite high.
- One feed frame will service all 48 stations on a production press. This implies smaller quantities of explosives on the press, reduced maintenance problems and more simplified explosive supply systems.
- MRC's detonator loading concept is very close in design to the SCAMP Tracer Charging Submodule which is being built by MRC. Consequently MRC can project an ultimate machine system of known cost.

RECOMMENDATIONS

MRC believes that the work performed on this contract demonstrates the feasibility of MRC's Gravity-Feed, Rotary Press loading concept. MRC therefore recommends the following:

- An engineering development program with extended testing to finalize design criteria for a prototype production machine.
- An extensive series of live tests on the bench model so that accurate reliability and maintainability estimates may be projected.
- Engineering programs to develop methods for orienting and feeding detonator cups and to develop an explosive supply system.
- A series of tests to define sympathetic detonation characteristics of the M-55 detonator in nests to determine the minimum in-line spacing of detonators on production machinery.

MRC believes that the work performed on this contract has been a positive step toward achieving the goal of a prototype production machine for loading non-electric detonators at the rate of 1200 per minute. MRC feels that it's Gravity-Feed, Rotary Press concept is sufficiently advanced to proceed directly into prototype production; but that the most cost effective approach for the Army is to fund additional testing, firmly establish machine interfaces and then proceed with fabrication of prototype machinery.

SUMMARY OF TESTS PERFORMED

During the course of this contract MRC performed a five step test program. Each step is listed below and discussed in subsequent paragraphs.

- Simulant Characterization Tests
- Preliminary Flow Tests
- Hazards Analysis
- Inert Loading Runs
- Live Loading Runs

SIMULANT CHARACTERIZATION TESTS

Simulants were used for all bench model tests performed during the engineering and fabrication phases of this contract because of the extreme sensitivity of the explosives utilized in the M55 detonator. Consequently MRC's initial investigations concentrated upon the determination of the physical characteristics of the government furnished simulants. Moisture analyses were run to assess the need for drying simulants. Various density characteristics and repose and slide angles were measured to aid in the design of the bench press. A tabulation of the results of these determinations may be found in Table 5, Appendix A.

PRELIMINARY FLOW TESTS

A simulator, which duplicates the rotational speed and diameter of a loading press, was built to aid in sizing the feed frame for the bench press. The simulator dial is 16 inches in diameter and contains five removable dies in which simulant can be collected. MRC's test procedure was as follows: (1) load simulant into feed frame; (2) run simulator for one revolution; (3) weigh the quantity of simulant metered into the die. Tables 6 to 8, Appendix A contain the data from these tests. The borax/wax mixture was the most flowable; the talc, the least flowable to the extent that a flow intensifier was required.

HAZARDS ANALYSIS

A subcontract was issued to Hercules Inc., Allegany Ballistics Laboratory, Cumberland, Maryland, to perform material response testing on the three explosives and a hazards analysis on MRC's loading system concept. The material response tests were performed prior to completion of the design phase of the contract so that any marginal design situations could be corrected prior to fabrication of hardware. The following tests were performed:

- Impact

- Friction
- Electrostatic Discharge
- Human Spark
- Impingement
- Dust Explosibility
- Thin Film Propagation
- Taliani
- Differential Scanning Calorimeter (DSC)

Bench press design completion followed the material response testing, and submission of the hazards analysis by ABL followed shortly thereafter. The specific results of the hazards analysis are discussed later in this report.

INERT AND LIVE LOADING RUNS

A series of inert loading runs with simulants were performed following fabrication of the bench press. This permitted mechanical checkout and debugging operations to be performed without the risks inherent with explosive testing. The data from these runs may be found in Appendix B. Because the press was undergoing mechanical alterations during the period that these tests were run, no attempts were made to correlate the data. However evaluation of the respective runs will give insight into the consistency of charge height and amount metered during a particular run.

MRC performed live loading runs after completion of the inert tests. An analysis of the live run data is presented in a subsequent section of this report. Tabulated data from the live runs are included in Appendix C.

BENCH MODEL DESCRIPTION

SYSTEMS CONCEPT

MRC's Gravity-Feed, Rotary Press loading concept utilizes three standard rotary compaction presses operating in sequence. A 1200 per minute system would include a cup feeder, an inserter for loading cups into nests, the three loading presses, several starwheels for directional changes and transfer between turrets, QC turrets and a nest recycle loop. Each loading press has 48 stations on a dial which rotates at 25RPM. The detonator cups enter the loading press open end down in nests. Explosives are contained within a feed frame. Nest alignment, metering of explosives and compaction of the explosive charge are controlled by cam guided upper and lower punches.

GENERAL DESCRIPTION OF BENCH PRESS

The bench loading press fabricated for this contract is identical in concept to the machinery projected in the preceeding paragraph. It utilizes one active station rotating at 25RPM. Consequently the operation of the bench press operating at 25 parts per minute exactly duplicates the operation of a 1200 ppm. production press because the 48 stations on a production machine are independent from each other. Nested detonator cups are stacked in a tube at the input station and are shuttled onto the dial by a cam operated feeder. An egress plough guides the loaded nests off the press following the compaction step. Figures one through four show various stages of the loading process. Figure five illustrates the operation of the feed frame.

OPERATING SEQUENCE

The following listing describes the operating sequence of the bench press:

- The upper punch is full up and the lower punch is full down as the die cavity passes under the feed frame.
- The explosive falls into the die cavity.
- Any excess explosive is returned to the feed frame as the lower punch travels upward on the doctor cam.
- The lower punch returns full down as the die cavity leaves the feed frame.
- One nest is fed onto the dial by the feed plate. Simultaneously the upper punch is being forced down by the cam track so that the tapered centering plunger of the punch enters the taper in the nest.

- The spring-loaded centering plunger compresses as the upper punch descends to support the detonator cup during the compaction step.
- The lower punch begins its ascent reaching the point of maximum compaction at the pressure rollers. The purpose of the rollers are to prevent sliding friction on the punch heads during the compression step.
- The upper and lower punches retract and the nest is guided off the press by the egress plough.

FEED FRAME

The bench model utilizes a feed frame for containment and feed of explosives, metering being performed by the lower punch acting in conjunction with the doctor cam. Consequently the feed frame is simply a device which allows controlled containment of explosives on the press dial. There are two basic types of feed frames: (1) the static type in which the powder being fed remains within the feed frame and (2) the dynamic type in which the powder is allowed to freely flow in and out of the feed frame. MRC has utilized static feed frames (see Figure 5) for the work performed on this contract because the static type requires the presence of less explosive on the dial than does the dynamic type, which is frequently used for independent pelleting operations.

There are three important considerations in the design of a feed frame: the bearing surface, the bearing pressure and the active feeding area. The bearing surface and pressure are of primary importance because of the velocity gradient that exists between the feed frame and dial; consequently, the resultant sliding friction at that interface represents a possible initiation mode. Sliding friction tests were performed during this program so that optimum material couples could be maintained for all three explosives. Oilon PV-80 plastic was found to be the preferred bearing surface material for RDX and NOL 130. Hardcoated aluminum is preferred for lead azide. Pressure at the feed frame/dial interface is kept to a minimum by utilizing floating, spring-loaded feed frames.

The other important consideration mentioned above is the active feeding area. Flowable explosives such as RDX and lead azide require small feeding areas whereas NOL 130 requires a large feeding area and vibration of one form or another to prevent bridging. MRC was successful in obtaining the maximum feeding area for a given feed frame length by separating the feed frame into several compartments. Because of the dial rotation, the explosive in the feed frame forms the triangular wedge shown in Figure 5. The most efficient feeding occurs at the leading edge of this wedge. By increasing the number of compartments in the feed frame, the number of optimal feeding locations are increased. Another benefit to this technique is that the quantity of explosive within the feed frame is reduced.

— Nest Feeder Accumulator Tube

— Upper Punch

— Feed Frame

Dial

Lower Punch

Die Cavity

— Doctor Cam

Bench Press
(Punches Leaving Feed Frame)

Figure 1

Upper Cam

Ingress Plough

Lower Cam

Feed Plate

Bench Press
(Punches at Nest Feeder)

Figure 2

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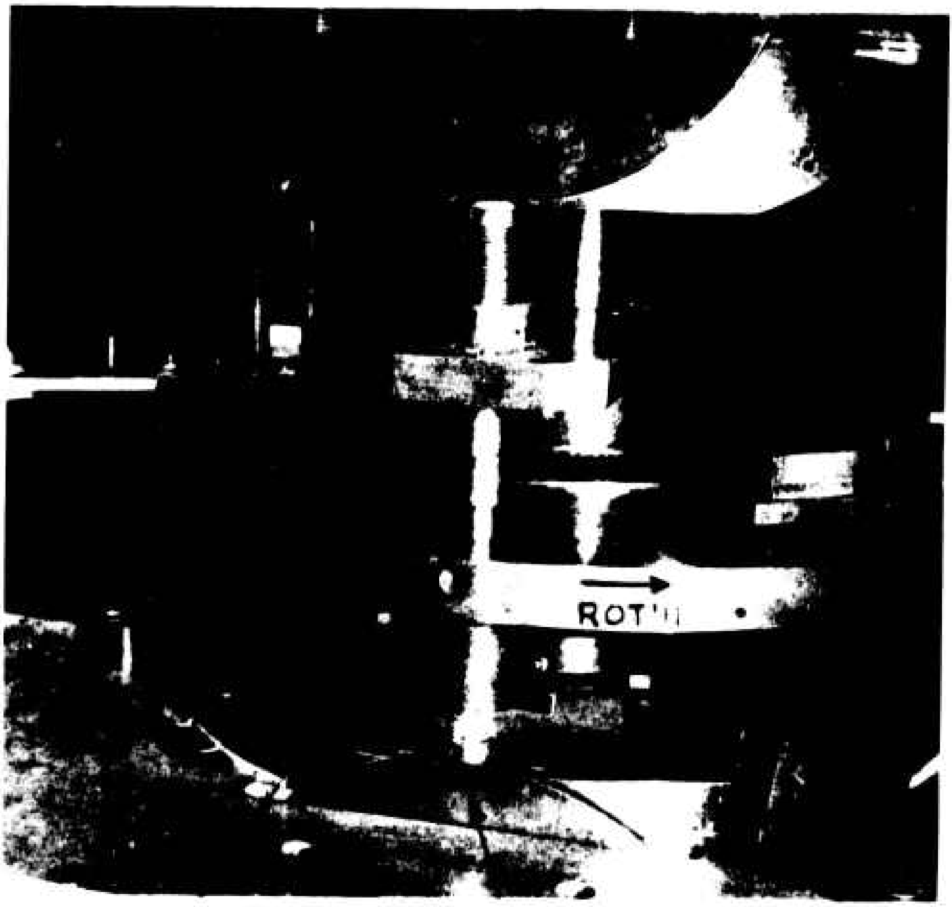
Upper Pressure Roll



Nest

Lower Pressure Roll

Bench Press
(Punches at Full Compaction)
Figure 3

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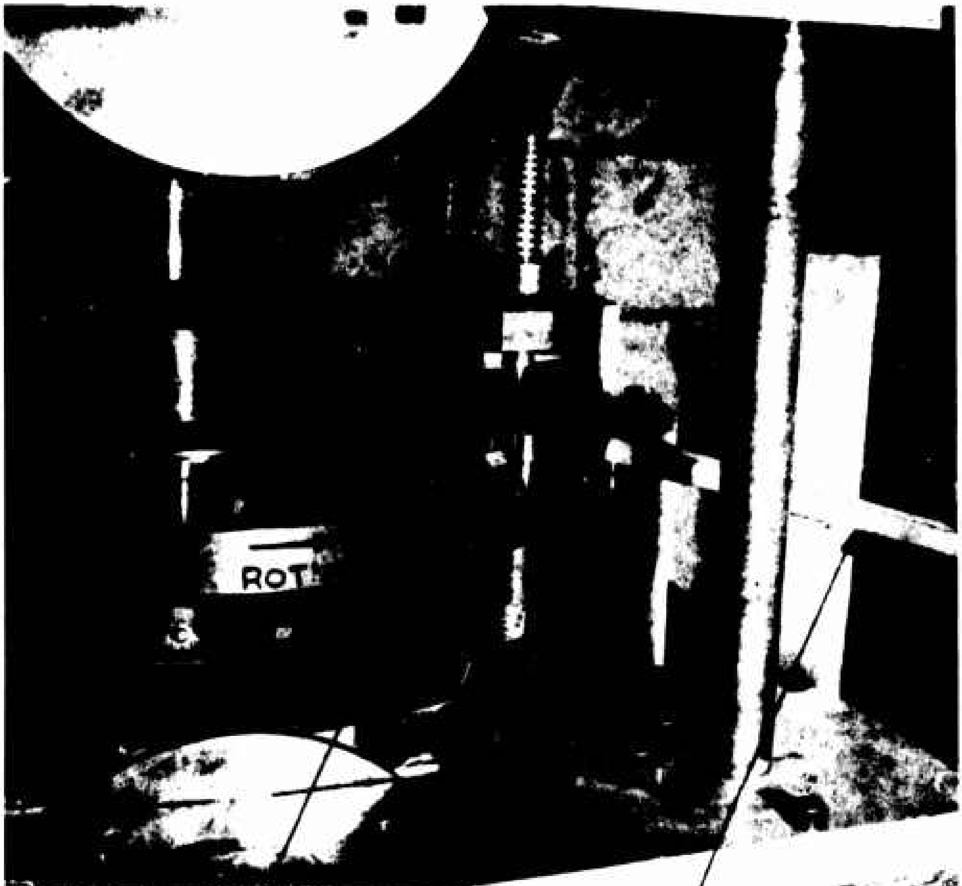

Bench Press
(Punches at Nest Ejection)
Figure 4

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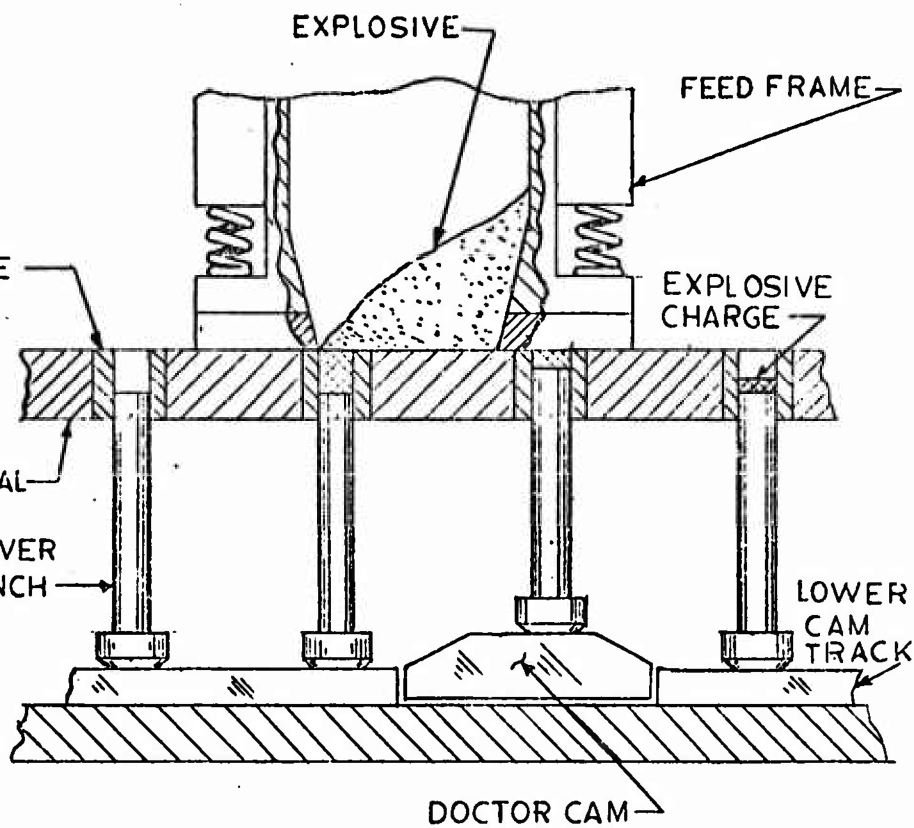

Feed Frame Operation

Figure 5

HAZARDS ANALYSIS

The results of the hazards analysis are summarized in Table 1, Table 2 and Table 3. Table 1 lists the major operations performed on the bench press, identifies the significant potential initiation hazards which might be present and by comparing the material response data with possible in-process stimuli, concludes whether or not a hazard does exist. Table 2 lists critical values for each of those potential hazards of Table 1 which could be subjected to a probit analysis. If the critical values are not exceeded, the probability of explosion due to a particular hazard is 10^{-6} for one-years continuous, two shift operation. Table 3 is a summary of design and operating criteria which would offer improved safety. It should be noted that the recommendations presented in Table 3 were implemented on the bench model since the hazards analysis was available prior to commencing live press runs.

Observation					Conclusion		
Potential Initiation Hazard	Combustible	Initiation Mode	In-Process Stimuli	Material Response	Hazard	Safety Margin	Probability of Initiation
Nested Cup Feed No explosive hazard when nests are clean							
Contaminated nests rubs on dial (Normal Transfer)	a.NOL-130 b.Lead Azide c.RDX	Friction between Steel/Steel	$\leq$1 psi @ 0.8 ft./sec	a.7250 psi @ 1 ft./sec b.28,300 @ 0.5 ft./sec c.66,700 @ 1 ft./sec	a.No b.No c.No	a.>7250 b.29,000 c.67,000	a. $< 1 \times 10^{-15}$ b. $< 1 \times 10^{-15}$ c. $< 1 \times 10^{-15}$
(Abnormal-Nest Cocked)	a.NOL-130 b.Lead Azide c.RDX	Friction between Steel/Steel	200,000 psi @ .8 ft./sec	a.7250 @ 1 ft./sec b.28,300 @ 0.5 ft./sec c.66,700 @ 1 ft./sec	a.Yes b.Yes c.Yes	a.None b.None c.None	a. > .99 b. 0.98 c. 0.70
Explosive Feed and Dispensation Feed frame slides on dial							
(Abnormal-No governing device)	a.NOL-130 b.Lead Azide c.RDX	Friction between Steel/Oilon PV-80	14,500 psi @ 1.71 ft./sec	a.2500 @ 2 ft./sec b.23,100 @ 2 ft./sec c.25,200 @ 10 ft./sec	a.Yes b.Marginal c.No	a.None b. 2 c.> 2	a. 0.85 b. 2×10^{-4} c. 3×10^{-5}
(Normal-w/governing device)	a.NOL-130 b.Lead Azide c.RDX	Friction between Steel/Oilon PV-80	10 psi @ 1.71 ft./sec	a.2500 @ 2 ft./sec b.23,100 @ 2 ft./sec c.25,200 @ 10 ft./sec	a.No b.No c.No	a.250 b.2350 c.>2500	a. $< 1 \times 10^{-15}$ b. $< 1 \times 10^{-15}$ c. $< 1 \times 10^{-15}$
Powder Handling (Abnormal-No grounding)	a.NOL-130 b.Lead Azide c.RDX	ESD (Human Spark)	30,000 v. (0.03 joules)	a.13,000 v. (0.0022j) b.11,000 v. (0.0028j) c.>30,000 v. (0.5j)	a.Yes b.Yes c.Marginal	a.None b.None c.> 1	a. > 0.99 b. > 0.99 c. 5×10^{-4}
Nest Centering (Abnormal)	a.NOL-130 b.Lead Azide c.RDX	Friction between Steel/Steel	8833 psi @ 0.02 ft./sec	a.27,500 @ .125 ft./sec b.39,200 @ .125 ft./sec c.66,700 @ 1 ft./sec	a.No b.No c.No	a. 3 b. 4 c. 8	a. 5×10^{-16} b. 3×10^{-3} c. $< 2 \times 10^{-5}$

HAZARDS ANALYSIS SUMMARY

TABLE 1

Observation					Conclusion		
Potential Initiation Hazard	Combustible	Initiation Mode	In-Process Stimuli	Material Response	Hazard	Safety Margin	Probability of Initiation
Normal-w/governing device which limits force to 10 lb force	a.NOL-130 b.Lead Azide c.RDX	Friction between Steel/Steel	50 psi @ 0.02 ft /sec	a.27,500 @ .125 ft./sec b.39,200 @ .125 ft./sec c.66,700 @ 1 ft/sec	a.No b.No c.No	a. 550 b. 784 c.1334	a. $< 1 \times 10^{-15}$ b. $< 1 \times 10^{-15}$ c. $< 1 \times 10^{-15}$
				1 S/S — 2 S/PV-80	1 — 2	1 — 2	1 — 2
Foreign material in powder causes a jammed condition between feed/frame and dial	a.NOL-130 b.Lead Azide c.RDX	Friction between 1.Steel/Steel 2.Steel/PV-80	200,000 @ 1.7 ft./sec 14,500 @ 1.7 ft./sec	a.7250 @ 1 fps — 2500 @ 2 fps b.28,300 @ 0.5 fps — 23,100 @ 2 fps c.65,250 @ 2 fps — >25,200 @ 10 fps	a.Yes — Yes b.Yes — Marginal c.Yes — No	None — None None — 2 None — >2	> .99 — 0.85 0.99 — 2×10^{-4} 0.70 — 3×10^{-5}
Compaction							
Lower punch rubs on hole in dial	a.NOL-130 b.Lead Azide c.RDX	Friction between Steel/Steel	200,000 @ 0.1 ft./sec	a.27,500 @ 0.125 ft./sec b.39,200 @ .125 ft./sec c.66,000 @ 1 ft./sec	a.Yes b.Yes c.Yes	a.None b.None c.None	a. > 0.99 b. 0.90 c. 0.70
Lower punch rubs on cup if misaligned	a.NOL-130 b.Lead Azide c.RDX	Friction between Steel/Al	30,000 @ 0.1 ft./sec	a.15,400 @ 0.125 ft./sec b.44,300 @ 8 ft./sec c.52,000 @ 8 ft./sec	a.Yes b.Marginal c.Marginal	a.None b. 1-1/2 c. 2	a. 0.93 b. $< 4 \times 10^{-2}$ c. $< 5 \times 10^{-5}$
Nest Ejection No hazard if powder scavenging is effective If powder present	a.NOL-130 b.Lead Azide c.RDX	Friction between Steel/Steel	< 1 @ 2.58 ft./sec max.	a.7250 @ 1 ft./sec b.28,300 @ .5 ft./sec c.65,250 @ 2 ft./sec	a.No b.No c.No	a.>7250 b.>20,000 c.64,000	a. $< 1 \times 10^{-15}$ b. $< 1 \times 10^{-15}$ c. $< 1 \times 10^{-15}$

HAZARDS ANALYSIS SUMMARY CONT'D.

TABLE 1 CONT'D.

Observation					Conclusion		
Potential Initiation Hazard	Combustible	Initiation Mode	In-Process Stimuli	Material Response	Hazard	Safety Margin	Probability of Initiation
Scavenging							
Particles being carried in air stream impinges on turns and elbows in pipe	a.NOL-130 b.Lead Azide c.RDX	Impingement of particles	Air Stream Velocity Normal ~ 6000 ft./min.	a.>68,000 ft./min. b.8250 ft./min. c.>68,000 ft./min.	a.No b.Marginal c.No	a. > 11 b. ~ 1.4 c. > 11	
			Abnormal ~65,000 ft./min.	a.>68,000 ft./min. b.8250 ft./min. c.>68,000 ft./min.	a.Marginal b.Yes c.Marginal	a. > 1 b. None c. > 1	

HAZARDS ANALYSIS SUMMARY CONT'D.

TABLE 1 CONT'D.

Event	Frequency f	Probability of: Event Occurring E_p	Explosive Present C_p	Initiation to Fire F_p	Fire to Explosion R_p	Initiation 10^{-6} $I_p = f \cdot E_p \cdot C_p \cdot F_p \cdot R_p$	Critical Value
Feed Frame (FV80) slides on dial (steel) @ 1.71 ft/sec Normal operation (w/limiting device)	4.2×10^8	1	1	a. 1 b. 1 c. 10^{-3}	a. 1 b. 1 c. 10^{-3}	a. 2.4×10^{-15} b. 2.4×10^{-15} c. 2.4×10^{-9}	Do not exceed a. 30 psi b. 6,500 psi c. 10,000 psi
Powder Handling - Human Spark Initiation	1×10^4 (based filling NOL-130 - 5# hopper ~ every 40 min.)	1	1	a. 1 b. 1 c. 10^{-3}	a. 1 b. 1 c. 10^{-3}	a. 1×10^{-10} b. 1×10^{-10} c. 1×10^{-4}	Do not exceed a. 0.0001 joules b. 0.0001 joules c. 0.05 joules (or 1000 volts)
Foreign Material causes jamming between feed frame and dial @ 1.7 ft/sec	1×10^4 (time 5# hopper filled)	1×10^{-3}	1	a. 1 b. 1 c. 10^{-3}	a. 1 b. 1 c. 10^{-3}	a. 1×10^{-7} b. 1×10^{-7} c. 1×10^{-1}	Steel/Steel — Steel/FV80 a. 700 psi — 200 psi b. 2,000 psi — 11,000 psi c. 60,000 psi — 25,000 psi
Lower Punch rubs on hole in dial (Steel/Steel) Abnormal condition - punch misaligned	5×10^4 based on no. of punches X failure rate	1	1	a. 1 b. 1 c. 10^{-3}	a. 1 b. 1 c. 10^{-3}	a. 2×10^{-11} b. 2×10^{-11} c. 2×10^{-5}	a. 300 psi b. 800 psi c. 10,000 psi
Lower Punch rubs on Al cup Abnormal condition	5×10^4	1	1	a. 1 b. 1 c. 10^{-3}	a. 1 b. 1 c. 10^{-3}	a. 2×10^{-11} b. 2×10^{-11} c. 2×10^{-5}	a. 2,800 psi b. 1,500 psi c. 30,000 psi
Nest Feed Nest (steel) rubs on dial (steel) @ 0.8 ft/sec Normal transfer	4.2×10^8	1	1×10^{-3}	a. 1 b. 1 c. 10^{-3}	a. 1 b. 1 c. 10^{-3}	a. 2.4×10^{-12} b. 2.4×10^{-12} c. 2.4×10^{-6}	Design so as not to exceed a pressure of a. 250 psi b. 600 psi c. 7,000 psi
Abnormal: Nest cocked	4.2×10^8	1×10^{-5}	1×10^{-3}	a. 1 b. 1 c. 10^{-3}	a. 1 b. 1 c. 10^{-3}	a. 2.4×10^{-7} b. 2.4×10^{-7} c. 2.4×10^{-1}	a. 900 psi b. 2,500 psi c. 90,000 psi
Nest Centering Nest(s) slides on dial(s) @ 0.02 ft/sec Normal operation	4.2×10^8	1	1	a. 1 b. 1 c. 10^{-3}	a. 1 b. 1 c. 10^{-3}	a. 2.4×10^{-15} b. 2.4×10^{-15} c. 2.4×10^{-9}	Do not exceed a. 160 psi b. 360 psi c. 3,000
Upper punch(s) rubs on detent of nest(s) @ 0.02 ft/sec Normal operation (Limiting device)	4.2×10^8	1	1	a. 1 b. 1 c. 10^{-3}	a. 1 b. 1 c. 10^{-3}	a. 2.4×10^{-15} b. 2.4×10^{-15} c. 2.4×10^{-9}	a. 9,000 psi b. 400 psi c. 3,000 psi
Nest Ejection - Same as for Nest Feed							

Note: a, b and c represent conditions for NOL-130, Lead Azide and RDX, respectively.

CRITICAL VALUES

TABLE 2

TABLE 3

DESIGN AND OPERATING CRITERIA

Operation	Criteria
Nested Cup Feed (or ejection)	a. If a pressure of 250 psi resulting from the nest sliding on the dial is not exceeded, then a probability of explosion from this operation of 10^{-6} or less for 1 year's operation can be assigned.
	b. Take those steps necessary (inspection, repair, clean-up, etc.) to prevent mis-oriented or contaminated nests from entering the press.
Feed, dispensation, and loading of explosive material	a. Incorporate into the design of the feed frame a device (such as spring loading) to limit the force that can be exerted by the feed frame on the press dial. The force selected should take into consideration the wear characteristics of the feed frame liner and the spillage of powder as well as the friction potential. A force of 30 psi or less would result in a probability of explosion of 10^{-6} during 1 year's operation.
	b. Incorporate into the design means of preventing foreign material from entering the hoppers, e.g., screen and magnets, metal detectors, etc.
	c. Minimize the force on the upper punch through the use of a limiting device during the nest centering operation. A force resulting in a pressure of 160 psi or less would result in a probability of explosion of 10^{-6} during 1 year's operation.
Compaction	a. The misalignment or overextension of the lower punch should be avoided. In order to assure a probability of explosion of 10^{-6} or less during one year, the pressure resulting from the punch rubbing on the hole in the dial should be 300 psi or less.

TABLE 3 CONT'D.

DESIGN AND OPERATING CRITERIA

Operation	Criteria
Scavenging	a. Maintain air velocities at the minimum level necessary to convey the powder since there is a hazard of initiation by impingement at a level of 8250 ft/sec.
	b. Wet powder down at pick-up points to minimize the electrostatic potential.
	c. Insure proper grounding to minimize electrostatic build-up. Grounding is necessary i this operation as well as all operations where explosive material is present. A level of 0.0001 joules is the maximum energy allowable in order to obtain a probability of explosion of 10^{-6} in on year.

LIVE LOADING RUNS

MRC's original program plan for this contract made provisions for a short series of live loading runs with RDX, lead azide and NOL 130 in that order. However problems, that necessitated extensive testing with lead azide and NOL 130, were encountered. Consequently a substantial number of live runs were performed. Table 4 summarizes the live testing. Tabulations of the live test data can be found in Appendix C. Records were kept on the quantity of explosive metered for the live tests; however, no attempt was made to record the charge height because the ability to maintain a consistent charge height was demonstrated during the inert runs.

No problems were encountered during the RDX runs. A fixed (rigidly supported) five compartment feed frame with an Oilon PV-80 bearing surface was used for RDX. MRC performed two loading runs of 21 and 23 detonators respectively. The quantity of explosive metered ranged from 40 to 44 mg. which is considerably in excess of the 19 mg. required on the M-55 drawing. MRC did not attempt to reduce the weight of explosive metered since the objectives of this program were specifically to demonstrate feasibility and the ability of the bench press to meter less explosive was not in question.

Unfortunately the lead azide tests were more troublesome than the RDX runs. A detonation occurred during the first revolution of the initial lead azide run as the die cavity was passing under the feed frame. It was felt at the time that the detonation was caused by excessive pressure between the rigidly supported feed frame and the dial. A one compartment, floating feed frame was built to replace the fixed feed frame. The floating feature allowed for minimal pressure at the dial/feed frame interface. MRC continued to use the Oilon bearing surface. Tests were run on the modified rotary simulator, which was originally constructed for the preliminary flow tests, to determine if the new feed frame would work. The simulations showed promising results; however, another detonation occurred during a subsequent run on the bench press. The cause of this detonation, which occurred at the same general location as the first, was attributed to the moving shear plane of the steel die cavity. An unsuccessful attempt was made to use an Oilon die in place of the steel one. It was postulated that the lead azide crystals (0.1 to 1.0 mm. long) were becoming embedded in the feed frame bearing surface, and they were being initiated when the shear plane of the die cavity passed under the feed frame. MRC concluded that Oilon PV-80 was unsuitable for use with lead azide.

A new bearing surface was fabricated from hardcoat aluminum. Several loading runs, with and without nests, were run on the bench press. MRC logged a total duration of 78 minutes and loaded 67 detonator cups without a detonation. The quantity of explosive metered for the nest runs ranged between 21 and 30 mg. or approximately half the required charge. It was felt that this could be remedied by either increasing the size of the feed frame or adding additional small feed frames. A subsequent test utilizing a floating, five compartment feed frame was unsuccessful. Consequently MRC is of the opinion that several small, independent feed frames should be utilized on future equipment.

MRC began the NOL 130 testing with a series of simulator runs to determine the preferred bearing surface material. Oilon PV-80 was selected as the most promising candidate. Because of the propensit of NOL 130 to bridge, a pneumatic vibrator was used to induce flow. A five compartment, floating feed frame was fabricated to provide a larger feeding area than was available with the existing one compartmen feed frame. Numerous test runs were made, most of which were plagued with material feed problems. MRC eventually obtained successful runs after promoting migration of the NOL 130 within the feed frame by machining undercuts on the bearing surface lands between cavities. With this configuration metered weights ran as high as 21 mg. with good repeatability within the required 14 to 16 mg. region. Only one detonation occurred during the NOL 130 runs; however, this incident was caused by a faulty test setup.

MRC feels that substantial improvements in metering efficiency with NOL 130 are possible by (1) using nitrogen pulses to induce flow in lieu of a pneumatic vibrator and (2) using a dynamic feed frame to further promote powder migration and extend the active feeding area. The utilization of nitrogen bearing feed frames with all three explosiv would also be helpful in eliminating sliding friction at the feed frame dial interface.

It is MRC's opinion that the tests performed on this contract demonstrate conclusively the feasibility of MRC's Gravity-Feed, Rotary Loading Concept to load M-55 detonators at the rate of 1200 per minute. Reiterating, MRC has demonstrated the following:

- The ability of MRC's bench press to handle all three explosives under conditions which exactly duplicate those of a production machine.
- The ability to exceed the M55 drawing requirements for loading RDX.
- The ability to meet the M55 drawing requirements for loading NOL 130.
- The ability to meet the M55 drawing requirements for loading lead azide by the straight-forward addition of one or more independent feed frames of proven design to the existing bench press.

Run Number	Feed Frame And Test Configuration	Feed Frame Bearing Surface	Run Time (Minutes)	Cups Loaded	Remarks
RDX-1	Fixed, 5 compartment	Oilon PV-80	0.8	21	Weights metered from 40 to 44 mg.
RDX-2	Fixed, 5 compartment	Oilon PV-80	0.9	23	Weights metered from 40 to 43 mg.
LA-1	Fixed, 5 compartment	Oilon PV-80	-	-	Blow occurred on first pass of die cavity under feed frame.
LA-2	Fixed, 1 compartment on rotary simulator	Oilon PV-80	21	-	One blow occurred.
LA-3	Floating, 1 compartment on rotary simulator	Oilon PV-80	20	-	Floating feature incorporated to provide less pressure between feed frame and dial
LA-4	Floating, 1 compartment	Oilon PV-80	0.6	11	Blow occurred while metering 12th cup.
LA-5	Floating, 1 compartment with Oilon die cavity	Oilon PV-80	0.5	-	No nests fed. Blow occurred. MRC concluded that Oilon PV-80 was unsuitable for use with lead azide.
LA-6	Floating, 1 compartment	Hardcoat Aluminum	70	-	No nests fed.
LA-7	Floating, 1 compartment	Hardcoat Aluminum	1.2 5.9	33 -	Average weight metered was 21 mg. No nests fed.
LA-8	Floating, 1 compartment	Hardcoat Aluminum	1.3	34	Average weight metered was 24 mg. This run concluded the lead azide tests with the floating, 1 compartment, hardcoat aluminum feed frame. During the tests MRC logged a total duration of 78 minutes and loaded 67 cups without a detonation.

CHRONOLOGICAL LIVE TEST SUMMARY

TABLE 4

Run Number	Feed Frame And Test Configuration	Feed Frame Bearing Surface	Run Time (Minutes)	Cups Loaded	Remarks
NOL-1	Floating, 1 compartment on rotary simulator	Oilon PV-80, steel or hardcoat aluminum	45	-	Blows occurred with hardcoat aluminum feed frame. Other materials were satisfactory.
NOL-2	Floating, 1 compartment with vibrator	Oilon PV-80	16 0.6	- 18	No nests fed. Poor metering of explosive because there was insufficient material in the feed frame.
NOL-3	Floating, 5 compartment with vibrator	Oilon PV-80	6 0.6	- 17	No nests fed. Average weight metered 7 mg.
NOL-4	Floating 5 compartment with vibrator	Oilon PV-80	.1	1	Blow occurred on 2nd pass of die cavity under the feed frame. Cause of blow attributed to human error during test setup.
NOL-5	Floating, 5 compartment with vibrator. Feed frame lands were undercut to relieve shear forces between die cavity and feed frame	Oilon PV-80	2.0	50	Average weight metered was 8 mg.
NOL-6	Same as NOL-5 except that bearing surface was partially ground to limit the migration of explosive.	Oilon PV-80	20	51	Average weight metered was 7 mg.

CHRONOLOGICAL LIVE TEST SUMMARY

TABLE 4 CONT'D.

Run Number	Feed Frame And Test Configuration	Feed Frame Bearing Surface	Run Time (Minutes)	Cups Loaded	Remarks
NOL-7	Floating, 5 compartment with vibrator and no undercuts	Oilon PV-80	2.6	67	Unsatisfactory metering of explosive, attributed to no migration of material in feed frame.
NOL-8	Floating, 5 compartment with vibrator and slight undercuts cut on lands between compartments.	Oilon PV-80	2.1	54	Metered weights ran as high as 21 mg. with good repeatability in the 14 to 16 mg. region.
LA-9	Floating, 5 compartment	Hardcoat Aluminum	-	-	Blow occurred when die cavity first passed under feed frame. MRC concluded from this test that multiple, small, independent feed frames are required for lead azide.

CHRONOLOGICAL LIVE TEST SUMMARY

TABLE 4 CONT'D.

APPENDIX A

PRELIMINARY SIMULANT TESTS

SIMULANT CHARACTERISTICS			
Physical Characteristics	Borax/Wax	PVC	Talc
Simulant for:	RDX	Lead Azide	NOL 130
Bulk Density (g/cc)	0.859	0.486	0.423
Packing Density-Min. (g/cc)	0.955	0.531	---
Packing Density-Max. (g/cc)	1.067	0.655	---
Sample Moisture (%)	0.330	0.079	0.046
Angle of Repose (deg.)	30.0	32.0	53.1
Angle of Slide (deg.)	28.6	34.2	55.0

SIMULANT CHARACTERISTICS

TABLE 5

Run No.	Weight Delivered (grams)					
	Die Number					Average
	1	2	3	4	5	
1	.0405	.0367	.0375	.0358	.0381	.0377
2	.0398	.0357	.0372	.0355	.0371	.0370
3	.0399	.0362	.0358	.0371	.0370	.0372
4	.0395	.0377	.0383	.0370	.0394	.0384
5	.0393	.0377	.0375	.0371	.0378	.0379
6	.0378	.0355	.0353	.0356	.0361	.0360
7	.0390	.0375	.0367	.0351	.0376	.0372
8	.0390	.0358	.0382	.0367	.0381	.0375
9	.0382	.0368	.0386	.0365	.0375	.0375
10	.0382	.0367	.0363	.0355	.0387	.0371
						.0374

BORAX/WAX PRELIMINARY FLOW TESTS

TABLE 6

Run No.	Weight Delivered (grams)					
	Die Number					Average
	1	2	3	4	5	
1	.0177	.0195	.0202	.0185	.0191	.0190
2	.0200	.0209	.0226	.0221	.0223	.0216
3	.0196	.0204	.0202	.0198	.0198	.0199
4	.0205	.0216	.0225	.0219	.0216	.0216
5	.0207	.0214	.0224	.0222	.0226	.0218
6	.0198	.0214	.0226	.0221	.0229	.0217
7	.0206	.0214	.0226	.0225	.0228	.0219
8	.0207	.0213	.0223	.0217	.0227	.0217
9	.0203	.0208	.0221	.0223	.0227	.0216
10	.0209	.0213	.0223	.0218	.0210	.0214
						.0212

PVC PRELIMINARY FLOW TESTS

TABLE 7

Run Number	Weight Delivered (grams)						Remarks
	Die Number					Average	
	1	2	3	4	5		
1	.0096	.0108	-0-	.0103	.0100	.0081	No flow intensifier
2	.0063	.0069	.0049	.0064	.0056	.0060	
3	.0059	-0-	.0072	-0-	-0-	.0026	
4	.0191	-0-	.0056	-0-	-0-	.0049	
5	.0172	.0140	.0135	.0120	.0102	.0134	Used brush in feed frame as flow intensifier with bristle helix in the direction of movement
6	.0133	.0141	.0116	.0106	.0089	.0117	
7	.0140	.0123	.0099	.0101	.0070	.0106	
8	.0130	.0104	.0092	.0088	.0080	.0099	
9	.0127	.0104	.0104	.0086	.0078	.0099	
10	.0170	.0184	.0147	.0142	.0125	.0153	Same as above except bristle helix against direction of flow
11	.0159	.0166	.0145	.0145	.0108	.0144	
12	.0140	.0160	.0138	.0143	.0106	.0137	
13	.0139	.0143	.0129	.0131	.0101	.0128	
14	.0134	.0149	.0124	.0130	.0109	.0129	
15	.0108	.0127	.0105	.0111	.0083	.0107	Same as above except material in the feed frame was left undisturbed before runs
16	.0108	.0116	.0099	.0094	.0077	.0099	
17	.0098	.0096	.0087	.0094	.0067	.0088	

TALC PRELIMINARY FLOW TESTS

TABLE 8

APPENDIX B

INERT BENCH MODEL TESTS

Nest No.	Net Weight Metered (grams)	Charge Height (inches)	Nest No.	Net Weight Metered (grams)	Charge Height (inches)
1	.0189		16	.0188	
2	.0203		17	.0237	
3	.0197		18	.0196	
4	.0211		19	.0213	
5	.0205		20	.0212	
6	.0225		21	.0191	
7	.0206		22	.0187	
8	.0203		23	.0200	
9	.0190		24	.0202	
10	.0203		25	.0230	
11	.0209				
12	.0205				
13	.0175				
14	.0198				
15	.0197				

INERT BENCH MODEL TEST

RUN 1. BORAX/WAX

TABLE 9

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Nest No.	Net Weight Metered (grams)	Charge Height (inches)	Nest No.	Net Weight Metered (grams)	Charge Height (inches)
1	.0153	.138	16	.0149	.138
2	.0126	.133	17	.0156	.137
3	.0158	.141	18	.0172	.139
4	.0148	.139	19	.0163	.141
5	.0168	.137	20	.0167	.141
6	.0167	.129	21	.0140	.127
7	.0168	.137	22	.0150	.136
8	.0161	.138	23	.0172	.138
9	.0148	.138	24	.0176	.143
10	.0153	.138	25	.0166	.144
11	.0143	.138	26	.0163	.139
12	.0173	.142	27	.0167	.141
13	.0149	.143			
14	.0164	.137			
15	.0148	.139			

INERT BENCH MODEL TEST

RUN 2. BORAX/WAX

TABLE 10

Nest No.	Net Weight Metered (grams)	Charge Height (inches)	Nest No.	Net Weight Metered (grams)	Charge Height (inches)
1	.0130		16	.0193	
2	.0213		17	.0202	
3	.0207		18	.0205	
4	.0203		19	.0206	
5	.0221		20	.0201	
6	.0270		21	.0155	
7	.0180		22	.0192	
8	.0168		23	.0206	
9	.0209		24	.0198	
10	.0207				
11	.0209				
12	.0199				
13	.0209				
14	.0202				
15	.0184				

Note: Run 3 and Run 4 were sequential loads on the same detonator cups.

INERT BENCH MODEL TEST

RUN 3. PVC

TABLE 11

Nest No.	Net Weight Metered (grams)	Charge Height (inches)	Nest No.	Net Weight Metered (grams)	Charge Height (inches)
1	.0160	.140	16	.0177	.140
2	.0166	.138	17	.0174	.142
3	.0180	.136			
4	.0159	.139			
5	.0174	.138			
6	.0158	.138			
7	.0180	.141			
8	.0175	.144			
9	.0174	.139			
10	.0179	.139			
11	.0183	.141			
12	.0179	.141			
13	.0181	.139			
14	.0159	.142			
15	.0159	.137			

Note: Run 3 and Run 4 were sequential loads on the same detonator cups.

INERT BENCH MODEL TEST

RUN 4. BORAX/WAX

TABLE 11 CONT'D.

Nest No.	Net Weight Metered (grams)	Charge Height (inches)	Nest No.	Net Weight Metered (grams)	Charge Height (inches)
1	.0163		16	.0161	
2	.0158		17	.0148	
3	.0175		18	.0166	
4	.0173		19	.0169	
5	.0165		20	.0139	
6	.0138		21	.0168	
7	.0179		22	.0154	
8	.0172		23	.0161	
9	.0157		24	.0168	
10	.0157				
11	.0171				
12	.0161				
13	.0165				
14	.0162				
15	.0167				

INERT BENCH MODEL TEST

RUN 5. BORAX/WAX

TABLE 12

Nest No.	Net Weight Metered (grams)	Charge Height (inches)	Nest No.	Net Weight Metered (grams)	Charge Height (inches)
1	.0160		16	.0071	
2	.0145		17	.0068	
3	.0123		18	.0075	
4	.0103		19	.0090	
5	.0111		20	.0076	
6	.0147		21	.0059	
7	.0119		22	.0073	
8	.0103		23	.0062	
9	.0091		24	.0089	
10	.0090				
11	.0089				
12	.0069				
13	.0083				
14	.0092				
15	.0079				

Note: The above tests were run with reciprocating brushes used to intensify flow.

INERT BENCH MODEL TEST

RUN 6. TALC

TABLE 13

Nest No.	Net Weight Metered (grams)	Charge Height (inches)	Nest No.	Net Weight Metered (grams)	Charge Height (inches)
1	.0178		16	.0098	
2	.0126		17	.0069	
3	.0113		18	.0072	
4	.0098		19	.0079	
5	.0094		20	.0087	
6	.0115		21	.0091	
7	.0090		22	.0092	
8	.0101		23	.0080	
9	.0105		24	.0080	
10	.0090				
11	.0097				
12	.0101				
13	.0102				
14	.0087				
15	.0090				

Note: The above tests were run with reciprocating brushes used to intensify flow.

INERT BENCH MODEL TEST

RUN 7. TALC

TABLE 14

Nest No.	Net Weight Metered (grams)	Charge Height (inches)	Nest No.	Net Weight Metered (grams)	Charge Height (inches)
1	.0110		16	.0029	
2	.0087		17	.0058	
3	.0089		18	.0044	
4	.0081		19	.0040	
5	.0085		20	.0045	
6	.0085		21	.0033	
7	.0086		22	.0028	
8	.0071		23	.0026	
9	.0086		24	.0051	
10	.0049				
11	.0047				
12	.0058				
13	.0048				
14	.0044				
15	.0049				

Note: The above tests were run with reciprocating brushes used to intensify flow.

INERT BENCH MODEL TEST

RUN 8. TALC

TABLE 15

Nest No.	Net Weight Metered (grams)	Charge Height (inches)	Nest No.	Net Weight Metered (grams)	Charge Height (inches)
1	.0210		16	.0178	
2	.0181		17	.0172	
3	.0189		18	.0174	
4	.0107		19	.0218	
5	.0128		20	.0190	
6	.0129				
7	.0118				
8	.0140				
9	.0111				
10	.0166				
11	.0130				
12	.0183				
13	.0200				
14	.0107				
15	.0092				

INERT BENCH MODEL TEST

RUN 9. PVC

TABLE 16

Nest No.	Net Weight Metered (grams)	Charge Height (inches)	Nest No.	Net Weight Metered (grams)	Charge Height (inches)
1	.0177	.151			
2	.0184	.142			
3	.0199	.137			
4	.0175	.138			
5	.0175	.142			
6	.0175	.140			
7	.0176	.139			

INERT BENCH MODEL TEST

RUN 10. BORAX

TABLE 17

Nest No.	Net Weight Metered (grams)	Charge Height (inches)	Nest No.	Net Weight Metered (grams)	Charge Height (inches)
1	.0132	.037			
2	.0103	.032			
3	.0141	.037			
4	.0098	.033			
5	.0135	.036			
6	.0174	.045			
7	.0127	.036			

Note: Used brushes as flow intensifiers.

INERT BENCH MODEL TEST

RUN 11. TALC

TABLE 18

Nest No.	Net Weight Metered (grams)	Charge Height (inches)	Nest No.	Net Weight Metered (grams)	Charge Height (inches)
1	.0404	.147			
2	.0389	.146			
3	.0398	.147			
4	.0391	.147			
5	.0401	.137			
6	.0392	.137			
7	.0399	.137			
8	.0397	.137			
9.	.0409	.134			
10	.0412	.134			
11	.0397	.134			
12	.0398	.134			
13	No data taken	.133			
14	No data taken	.133			
15	No data taken	.133			

Note: Nests 1 through 4 with .120 Compaction Spacer
Nests 5 through 8 with .108 Compaction Spacer
Nests 9 through 16 with .106 Compaction Spacer

INERT BENCH MODEL TEST

RUN 12. BORAX/WAX

TABLE 19

Nest No.	Net Weight Metered (grams)	Charge Height (inches)	Nest No.	Net Weight Metered (grams)	Charge Height (inches)
1	.0177	.110	16	.0156	.075
2	.0187	.109	17	.0173	.074
3	.0174	.113	18	.0165	.075
4	.0177	.110	19	.0137	.077
5	.0185	.113	20	.0117	.078
6	.0183	.107	21	.0143	.085
7	.0185	.109	22	.0119	.082
8	.0185	.111	23	.0184	.080
9	.0179	.110	24	.0149	.085
10	.0182	.112	25	.0130	.077
11	.0170	.114	26	.0155	.080
12	.0179	.112	27	.0127	.083
13	.0182	.112	28	.0162	.080
14	.0169	.112	29	.0179	.080
15	.0187	.111	30	.0156	.083
			31	.0179	.077

INERT BENCH MODEL TEST

RUN 13. PVC

TABLE 20

Nest No.	Net Weight Metered (grams)	Charge Height (inches)	Nest No.	Net Weight Metered (grams)	Charge Height (inches)
1	.0174	.084	16	.0142	.087
2	.0185	.086			
3	.0182	.084			
4	.0178	.085			
5	.0172	.083			
6	.0164	.085			
7	.0146	.086			
8	.0143	.083			
9	.0150	.084			
10	.0153	.083			
11	.0147	.085			
12	.0147	.085			
13	.0147	.084			
14	.0153	.085			
15	.0148	.088			

INERT BENCH MODEL TEST

RUN 14. PVC

TABLE 21

Nest No.	Net Weight Metered (grams)	Charge Height (inches)	Nest No.	Net Weight Metered (grams)	Charge Height (inches)
1	.0179	.084	16	.0155	.085
2	.0156	.085			
3	.0163	.086			
4	.0156	.085			
5	.0163	.082			
6	.0163	.083			
7	.0157	.082			
8	.0157	.088			
9	.0144	.086			
10	.0152	.087			
11	.0156	.084			
12	.0160	.084			
13	.0160	.086			
14	.0160	.085			
15	.0154	.084			

INERT BENCH MODEL TEST

RUN 15. PVC

TABLE 22

Nest No.	Net Weight Metered (grams)	Charge Height (inches)	Nest No.	Net Weight Metered (grams)	Charge Height (inches)
1	.0181	.085	16	.0188	.084
2	.0181	.083			
3	.0181	.084			
4	.0188	.084			
5	.0187	.085			
6	.0187	.085			
7	.0188	.083			
8	.0189	.084			
9	.0189	.084			
10	.0189	.085			
11	.0185	.084			
12	.0185	.085			
13	.0188	.085			
14	.0188	.089			
15	.0183	.084			

INERT BENCH MODEL TEST

RUN 16. PVC

TABLE 23

Nest No.	Net Weight Metered (grams)	Charge Height (inches)	Nest No.	Net Weight Metered (grams)	Charge Height (inches)
1	.0213	.065	16	.0203	.063
2	.0207	.063	17	.0203	.062
3	.0192	.064	18	.0198	.064
4	.0195	.063	19	.0184	.060
5	.0201	.065	20	.0171	.058
6	.0173	.068	21	.0171	.059
7	.0193	.062	22	.0195	.063
8	.0211	.063	23	.0193	.061
9	.0179	.060	24	.0186	.060
10	.0210	.064	25	.0185	.063
11	.0195	.061	26	.0197	.065
12	.0199	.064	27	.0186	.061
13	.0216	.064	28	.0188	.061
14	.0185	.060	29	.0213	.065
15	.0184	.059	30	.0214	.063

INERT BENCH MODEL TEST

RUN 17. BORAX/WAX

TABLE 24

Nest No.	Net Weight Metered (grams)	Charge Height (inches)	Nest No.	Net Weight Metered (grams)	Charge Height (inches)
31	.0208	.062	41	.0170	.059
32	.0225	.065	42	.0175	.061
33	.0156	.059	43	.0181	.060
34	.0169	.059	44	.0176	.059
35	.0163	.057	45	.0160	.058
36	.0164	.057	46	.0174	.059
37	.0151	.057	47	.0208	.063
38	.0168	.058	48	.0183	.060
39	.0147	.058	49	.0194	.064
40	.0173	.059	50	.0183	.061

INERT BENCH MODEL TEST

RUN 17 CONT'D. BORAX/WAX

TABLE 24

APPENDIX C

LIVE BENCH MODEL TESTS

Series Number	Weight Metered (grams)	Series Number	Weight Metered (grams)	Series Number	Weight Metered (grams)
1	.0402	3	.0410		
2	.0438	3	.0408		
2	.0429	3	.0408		
2	.0408				
3	.0428				
3	.0430				
3	.0437				
3	.0412				
3	.0407				
3	.0405				
3	.0411				
3	.0399				
3	.0412				
3	.0426				
3	.0408				
3	.0412				
3	.0426				
3	.0430				

Feed Frame Type: X Fixed ____ Floating(1 Compartment)

____ Floating(5 Compartments)

Bearing Surface: X Oilon, PV-80 ____ Hardcoat Aluminum

RUN RDX-1

TABLE 25

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Series Number	Weight Metered (grams)	Series Number	Weight Metered (grams)	Series Number	Weight Metered (grams)
1	.0400	4	.0397		
2	.0428	4	.0399		
2	.0422	4	.0418		
2	.0433	4	.0404		
3	.0426	4	.0420		
3	.0421				
4	.0428				
4	.0427				
4	.0413				
4	.0410				
4	.0422				
4	.0412				
4	.0426				
4	.0430				
4	.0407				
4	.0400				
4	.0418				
4	.0426				

Feed Frame Type: __X__ Fixed _____ Floating (1 Compartment)

_____ Floating (5 Compartments)

Bearing Surface: __X__ Oilon, PV-80 _____ Hardcoat Aluminum

RUN RDX-2

TABLE 26

Series Number	Weight Metered (grams)	Series Number	Weight Metered (grams)	Series Number	Weight Metered (grams)
3	.0236				
3	.0235				
3	.0242				
4	.0210				
4	.0161				
4	.0143				
4	.0223				
5	.019				
5	.019				
5	.024				

Feed Frame Type: ____Fixed X Floating(1 Compartment)

____Floating(5 Compartments)

Bearing Surface: X Oilon, PV-80 ____Hardcoat Aluminum

RUN LA-4

TABLE 27

Series Number	Weight Metered (grams)	Series Number	Weight Metered (grams)	Series Number	Weight Metered (grams)
1	.0284	2	.0018		
1	.0156	2	.0199		
1	.0126	2	.0233		
1	.0200	2	.0423		
1	.0113	2	.0236		
1	.0206				
2	.0343				
2	.0262				
2	.0244				
2	.0211				
2	.0233				
2	.0178				
2	.0235				
2	.0232				
2	.0222				
2	.0229				
2	.0116				
2	.0230				

Feed Frame Type: ____Fixed _X_ Floating(1 Compartment)

____Floating(5 Compartments)

Bearing Surface: ____Oilon, PV-80 _X_ Hardcoat Aluminum

Note: No Compaction On Ten Additional Cups

RUN LA-7

TABLE 28

Series Number	Weight Metered (grams)	Series Number	Weight Metered (grams)	Series Number	Weight Metered (grams)
1	.0253	2	.0268		
1	.0260	2	.0267		
1	.0267	2	.0278		
1	.0244	2	.0252		
1	.0132	2	.0269		
1	.0230	2	.0250		
1	.0247	2	.0261		
1	.0261	2	.0215		
1	.0234	2	.0219		
1	.0246	2	.0228		
1	.0227	2	.0227		
1	.0244	2	.0216		
1	.0231	2	.0243		
1	.0242	2	.0232		
1	.0243	2	.0227		
1	.0263	2	.0200		
1	.0262	2	.0167		

Feed Frame Type: ____Fixed _X_ Floating(1 Compartment)

____Floating(5 Compartments)

Bearing Surface: ____Oilon, PV-80 _X_ Hardcoat Aluminum

RUN LA-8

TABLE 29

Series Number	Weight Metered (grams)	Series Number	Weight Metered (grams)	Series Number	Weight Metered (grams)
3	.0021				
3	.0087				
3	.0080				
3	.0095				
3	.0077				
3	.0092				
3	.0082				
3	.0104				
3	.0001				
3	.0094				
3	.0101				
3	.0014				
3	.0098				
3	-0-				
3	.0080				

Feed Frame Type: ____Fixed ____Floating(1 Compartment)

X Floating(5 Compartments)

Bearing Surface: X Oilon, PV-80 ____Hardcoat Aluminum

RUN NOL-3

TABLE 30

Series Number	Weight Metered (grams)	Series Number	Weight Metered (grams)	Series Number	Weight Metered (grams)
NOL 4-1	.0204	2	.0065	3	.0130
1	.0153	2	.0094	3	.0143
1	.0146	2	.0065	3	.0129
1	.0140	2	.0061	3	.0111
1	.0097	2	-0-	3	.0095
1	.0102	2	.0058	3	.0108
1	.0090	2	-0-	3	.0102
1	.0087	2	-0-	3	.0066
1	.0096	2	.0073	3	.0080
1	.0082	2	-0-	3	.0077
1	.0083	2	.0022	3	.0081
1	.0095	2	.0004	3	.0080
1	.0101	2	.0002	3	.0071
1	.0104	2	-0-	3	.0068
1	.0077	2	.0059	3	.0059
1	.0075	2	.0062	3	.0070
1	.0085	2	.0063		
1	.0073				

Feed Frame Type: ____Fixed ____Floating(1 Compartment)

X Floating(5 Compartments)

Bearing Surface: X Oilon, PV-80 ____Hardcoat Aluminum

RUN NOL-5

TABLE 31

Series Number	Weight Metered (grams)	Series Number	Weight Metered (grams)	Series Number	Weight Metered (grams)
1	.0140	2	.0042	3	.0111
1	.0148	2	.0048	3	.0107
1	.0143	2	.0024	3	.0108
1	.0123	2	-0-	3	.0080
1	.0123	2	.0060	3	.0086
1	.0123	2	.0020	3	.0100
1	.0099	2	.0060	3	.0100
1	.0115	2	.0010	3	.0102
1	.0085	2	.0008	3	.0089
1	.0010	2	.0006	3	.0076
1	.0067	2	.0089	3	.0085
1	.0012	2	.0009	3	.0002
1	.0006	2	.0018	3	.0096
1	.0006	2	-0-	3	.0097
1	.0086	2	.0102	3	.0093
1	.0062	2	.0005	3	.0104
1	.0118	2	.0121	3	.0094

Feed Frame Type: ____ Fixed ____ Floating(1 Compartment)

X Floating(5 Compartments)

Bearing Surface: X Oilon, PV-80 ____ Hardcoat Aluminum

RUN NOL-6

TABLE 32

Series Number	Weight Metered (grams)	Series Number	Weight Metered (grams)	Series Number	Weight Metered (grams)
1	.0098	2	-0-		
1	.0105	2	.0068		
1	-0-	2	.0020		
1	-0-	2	-0-		
1	.0033	2	-0-		
1	-0-	2	.0056		
1	.0050	2	.0034		
1	.0060	2	-0-		
1	.0076	2	.0050		
1	.0074	2	.0020		
1	.0047	2	.0070		
1	.0003	2	.0074		
1	-0-	2	.0058		
1	.0275	2	.0060		
1	.0267	2	.0042		
1	.0030	2	.0059		
1	.0094	2	.0072		
		2	.0190		

Feed Frame Type: ____ Fixed ____ Floating (1 Compartment)

X Floating (5 Compartments)

Bearing Surface: X Oilon, PV-80 ____ Hardcoat Aluminum

RUN NOL-7

TABLE 33

Series Number	Weight Metered (grams)	Series Number	Weight Metered (grams)	Series Number	Weight Metered (grams)
1	.0109	2	.0021	3	.0188
1	.0007	2	.0057	3	.0180
1	.0003	2	-0-	3	.0166
1	.0006	2	.0009	3	.0168
1	.0022	2	-0-	3	.0145
1	.0008	2	.0015	3	.0144
1	.0010	2	.0001	3	.0114
1	.0009	2	.0001	3	.0125
1	.0008	2	-0-	3	.0085
1	.0003	2	.0001	3	.0086
1	.0015	2	.0002	3	.0008
1	.0015	2	.0006	3	.0143
1	.0001	2	.0015	3	.0082
1	.0008	2	.0015	3	.0138
1	.0001	2	.0120	3	-0-
1	.0010	2	.0004	4	.0156
1	.0095	3	.0184	4	.0113
2	.0016	3	.0213	4	.0119

Feed Frame Type: ____ Fixed ____ Floating (1 Compartment)

_X_ Floating (5 Compartments)

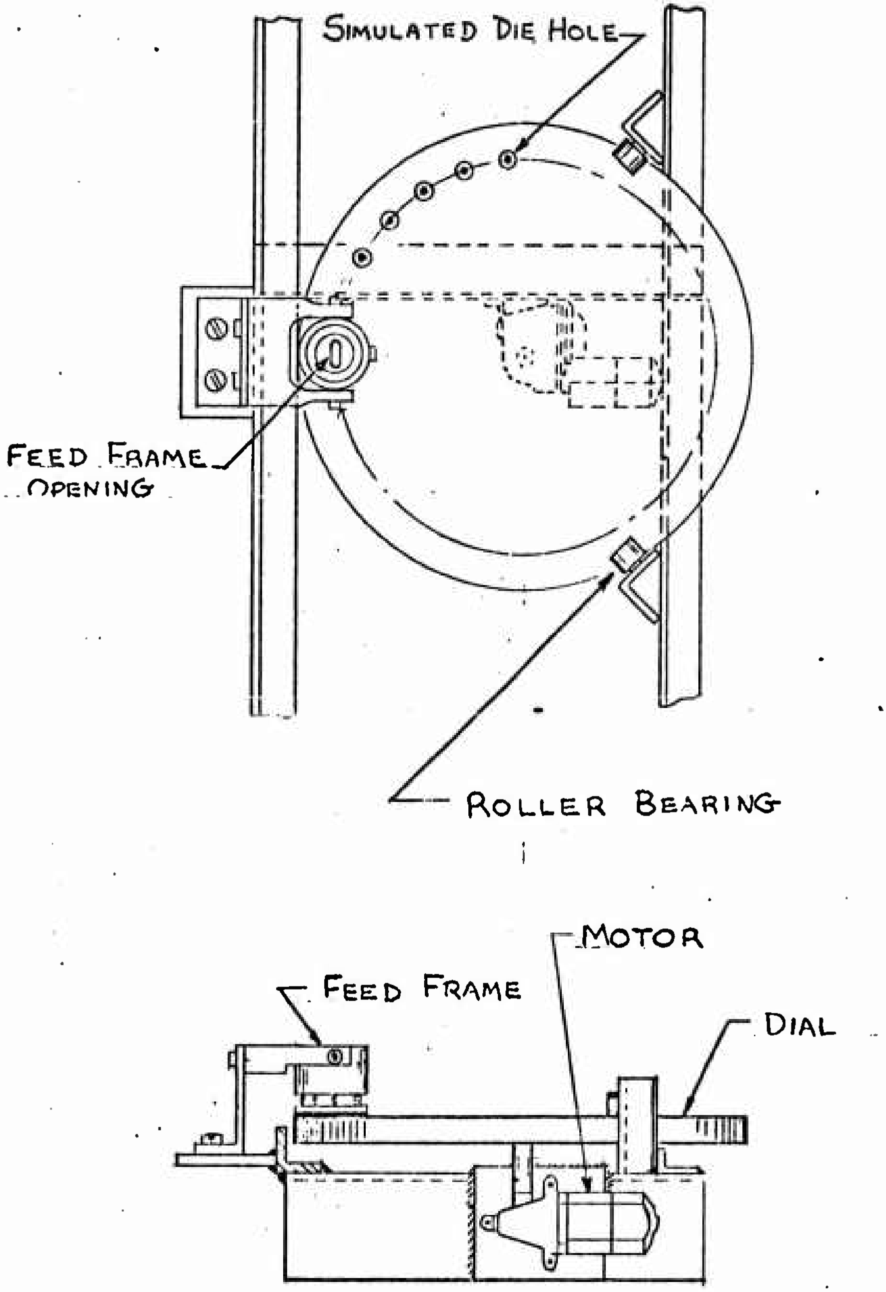
Bearing Surface: _X_ Oilon, PV-80 ____ Hardcoat Aluminum

RUN NOL-8

TABLE 34

APPENDIX D

PRESS SIMULATOR



Press Simulator

Figure 6

PRESS SIMULATOR

Figure 6 is a schematic and Figure 7 is a photograph of the press simulator. The diameter of the simulator dial and the bolt circle diameter of the simulated die holes were identical with the bench press. A variable speed drive motor was used. Inert and live runs were performed on the simulator throughout the course of this contract.

Press Simulator

Figure 7